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QUADRUPED MOTION ROBOT

MOHAMMAD AZRAI B MOHD NORRAZI

A thesis submitted in partial fulfillment
of the requirements for the award of the degree of
Bachelor of Engineering (Electrical- Mechatronics)

Faculty of Electrical Engineering
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Specially dedicated to my family, lectures, teachers and fellow friends who have encouraged, guided and inspired me throughout my journey of education

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ABSTRACT

The establishment of autonomous hybrid leg-wheel robot which “quadruped motion robot” has long been an important issue in robot design. Numerous studies have been conducted by leading universities world and industry. The body of knowledge in this thesis is that applies to the theory of concerning development of the four leg robot, design mechanical, and the electronic. This project will construct an autonomous hybrid leg-wheel robot which equipped with eight servomotors as leg actuators and 4 as servomotors as a wheel and it will focus on its capabilities to perform optimization of gait patterns on a legged mode with implementation of wheel mode on flat surface or rough surface. The main interactive sense is the ability of the robot to interact with the other object and avoiding obstacle. In this thesis a brief introduction is given in theory of concerning development of the autonomous hybrid leg-wheel robot in flat surface or rough surface such as Track-changeable Quadruped Walking Robot "TITAN X"**,** Roller Walker, Autonomous quadruped robot (UTM), and MAAT-1. In order to achieve the goal of enhancing the project planning, designing, and implementing capabilities, and this thesis aims to use PIC18F4520 microcontroller as the major controller to develop a working autonomous mobile robotic system. This robot also has the function to avoid obstacles using IR sensors and analog distance sensors. This robot is built using two pieces of the DC motor as the engine. This robot can move forward, back and turn left and right and C language program was used to introduce programs for the chip by using MPLAB for the robot to function properly and thoroughly. Hoped that this thesis will provide adequate information to anyone who is interested to learn and understand to learn and to understand the nature and capabilities of autonomous hybrid leg-wheel robot.

ABSTRAK

Penubuhan autonomi robot hibrid kaki-beroda yang "gerakan robot berkaki empat" telah lama menjadi isu penting dalam reka bentuk robot. Bagi pendekatan dalam tesis ini adalah berfokus kepada teori berkenaan pembangunan robot empat kaki, reka bentuk mekanikal dan elektronik. Projek ini akan membina autonomi hibrid kaki-beroda robot yang dilengkapi dengan lapan servomotor sebagai penggerak kaki dan 4 servomotor sebagai roda dan ia akan memberi tumpuan kepada keupayaannya untuk melaksanakan corak gaya berjalan mod berkaki dengan pelaksanaan mod roda pada permukaan yang rata atau permukaan kasar. Rasa interaktif utama adalah kebolehan robot untuk berinteraksi dengan objek yang lain dan mengelakkan halangan. Dalam tesis ini pengenalan ringkas diberikan dalam teori mengenai pembangunan autonomi robot kaki beroda hibrid di permukaan yang rata atau permukaan kasar seperti berkaki empat Track-berubah-ubah Walking Robot "TITAN X", Roller Walker, Autonomi berkaki empat robot (UTM),dan MAAT-1. Bagi mencapai matlamat meningkatkan perancangan projek, merekabentuk, dan melaksanakan keupayaan dan tesis ini bertujuan untuk menggunakan mikropengawal PIC18F4520 sebagai pengawal utama untuk membangunkan sistem kerja mudah alih robot autonomi. Robot ini juga mempunyai fungsi untuk mengelakkan halangan-halangan yang menggunakan sensor IR dan sensor jarak analog. Robot ini dibina dengan menggunakan dua keping motor AT sebagai enjin. Robot ini boleh bergerak ke hadapan, belakang dan berpaling kiri dan kanan dan program bahasa C telah digunakan untuk memperkenalkan program-program untuk cip tersebut dengan menggunakan MPLAB bagi robot berfungsi dengan betul dan teliti. Berharap bahawa tesis ini akan menyediakan maklumat yang mencukupi kepada sesiapa yang berminat untuk belajar dan memahami untuk belajar dan untuk memahami sifat dan keupayaan autonomi robot hibrid kaki beroda.

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LIST OF SYMBOLS AND ABBREVIATIONS

LCD	Liquid Crystal Display
IR	Infrared
deg	Degree
GUI	Graphic User Interface
ms	millisecond
us	Microsecond
MCU	Microcontroller Unit
EEPROM	Electrically Erasable Programmable Read-Only Memory
MPLAB	Microchip Technology Inc. The Embedded Control Solutions Company®
LED	Light Emitting Diode
PIC	Harvard architecture microcontrollers made by Microchip Technology

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CHAPTER 1

1.0 INTRODUCTION

1.1 Background

Legged robot shows very good interaction in terms of stability, payload capabilities, and dynamic behavior. Thus, usually they are focus a very important source of inspiration and idea for designing legged systems mainly narrow from the mechatronic design to the path planning and gait generation locomotion. Most of the researchers have focused and studies lot of these topics by using a multi approach such as animal, human, mobile or by combine both wheel and leg. For example, several studies have been addressed to the transmission system of vertebrate legged animals from a kinematic point of view. In fact, bones and articulations can be easily modeled as links and joints of a kinematic architecture. Examples of for biped, quadruped and hexapod locomotion in nature are shown in Figure 1.1 to 1.3 with their simplified kinematic architectures. Those animals have been and still are inspiration both for design and operation of walking legged systems. In the following main features are reported for each animal but more details can be and have been considered in inspiring/mimicking for walking legged systems.[1]

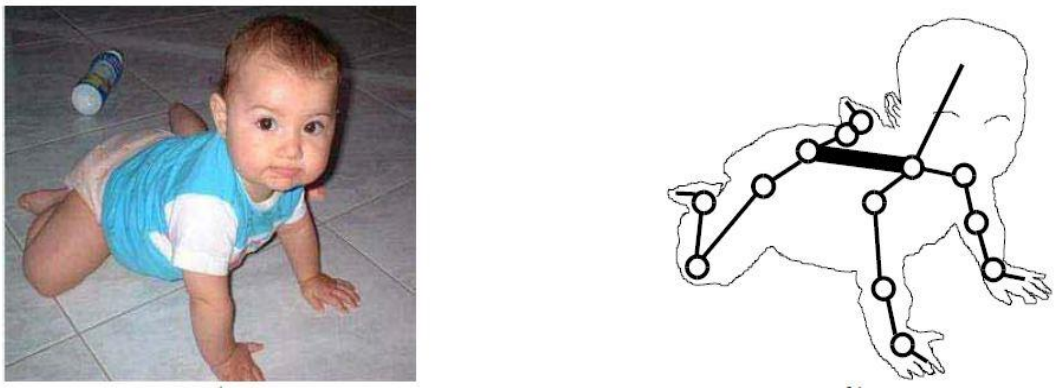


Figure 1.1: Quadruped locomotion by a young child and kinematic scheme

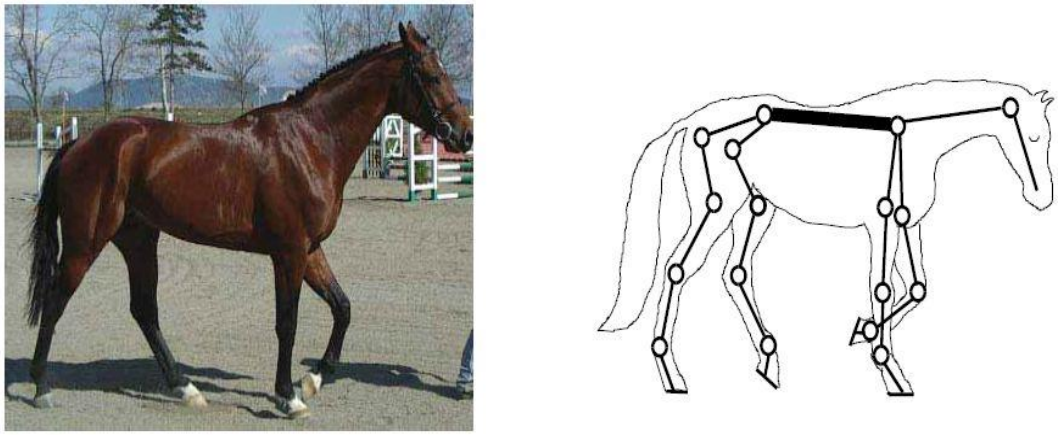


Figure 1.2: Quadruped locomotion by a horse and kinematic scheme

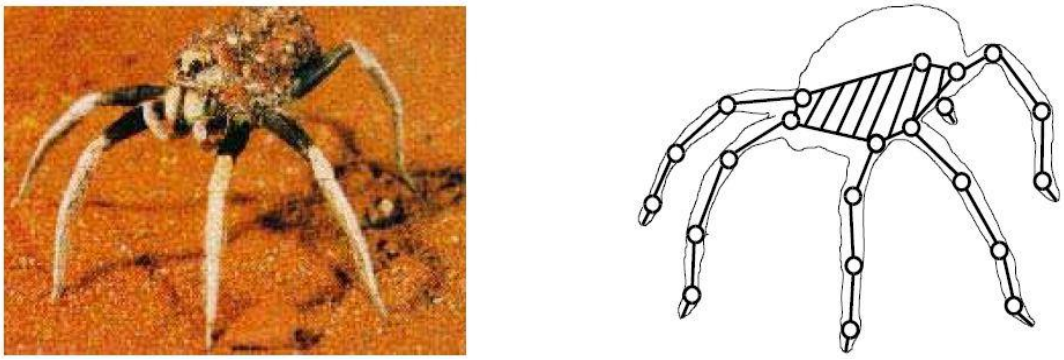


Figure 1.3: Hexapod locomotion by a spider and kinematic scheme[1]

In this thesis we will cover most of the mobile robots rely on wheels for locomotion but it faces difficulties on controlling and moving on uneven terrain such as grass, sand and grumble surface. Wheeled mobile robot divide by two type driving configuration - steer drive and differential-drive. Differential drive have configuration that requires a somewhat more complex control strategy than the steer – drive configuration, because it capability of making small – radius turns, even

making turns on – the – spot, makes it the first choice in many industrial applications.

However, it has a problem when dealing with obstacles which legged robot can overcome this problem despite its design is complicated and not cost effective because of legged robots include their ability to traverse rough terrain with good body stability and minimal ecological damage. The common legged robots normally built are biped, quad and hexapod. The stability of legged robot is crucial part in designing it because robot must shift to its center of gravity during walk to maintain stability.

1.2 Problem Statement

At present, there are many student and collage studies about leg-wheel hybrid mobile robot because walking robot has high terrain adaptability on irregular ground but wheeled robot takes advantage of moving speed on smooth terrain. Active wheels were often used for wheeled locomotion. However, by installation of wheels into walking mode restricted the ability very much because active wheels need engine, stability, actuators, brake mechanism and steering mechanism. This equipment is so heavy and bulky that it's not practical solution for walking robot which has many degrees of freedom. As mobile robots are required to operate in increasingly challenging environments, the limitations of traditional wheeled and tracked vehicle designs become increasingly, apparent their simple and robust design does not provide sufficient versatility and adaptability for many real-world terrain conditions. Design modifications, which add passive or active degrees of freedom with or without compliance, can be made to make these vehicles better suited to rough terrain. The constraints and challenges that been discuss had bring an inspiration and aspiration to me to design and construct an autonomous hybrid leg-wheel quadruped robot.

1.3 Objective

This project will design and construct an autonomous hybrid leg-wheel robot which equipped with twelve servomotors as leg actuators and it will focus on its capabilities to perform optimization of gait patterns on a legged mode with implementation of wheel mode on flat surface. The robot will combining with interactive of environment sense. The main interactive sense is the ability of the robot to interact with the other object and avoiding obstacle. Variety modes of movement will activated autonomously by a looping program with mode selection.

1.4 Project Scope

The project of quadruped motion robot will mainly focus on its capabilities of robot that can switch a legged mode and the implementation of wheel mode on flat surface. A wide research, references and bench marking with previous and interrelated project will also be gone through to study their achievement, constrains, ideas and fulfill the aims to build a stable, organic and robust quadruped robot. Basically the quadruped robot project is to design and build a hybrid leg-wheel robot that can changes between feet soles for the walking mode and wheels for the wheel mode. Variety modes will attach to robot movement for the outcome such as walking and turning with legged mode, implementation of wheel mode on flat surface, pass forward obstacles, obstacle avoidance and with high speed walking mode.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Introduction

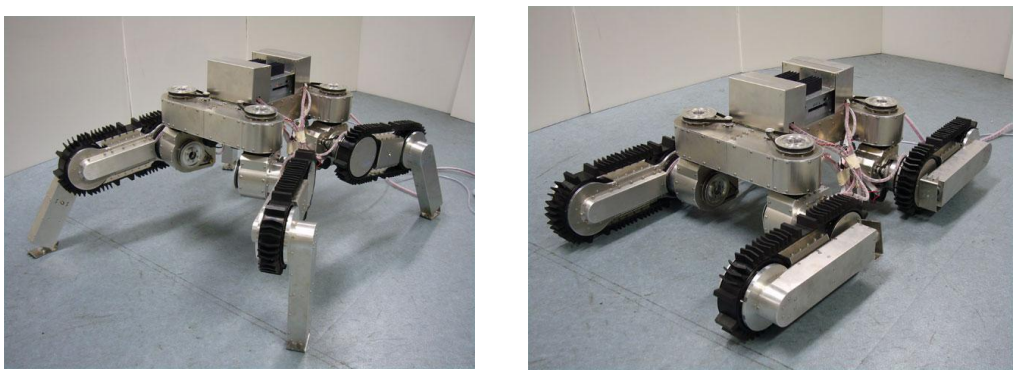
There are many studies about leg-wheel or leg-track hybrid mobile robot because walking robot has high terrain adaptability on rough terrain but wheeled or tracked robot have advantages of mobile speed on level terrain. However, conventional hybrid mobile machines are restricted because they are equipped with leg driving system and wheeled or tracked driving system separately and the addition of multiple driving systems causes the robot to gain weight and grow in size. In many cases, wheeled or tracked mechanism do not contribute to walking because these mechanisms are used while the leg mechanisms are being driven.

2.2. Track-changeable Quadruped Walking Robot "TITAN X"[11]

Roller-Walker is a walking machine with a special foot mechanism on each leg which changes to a sole in leg form and a passive wheel in skating form.

Effectiveness of constructing hybrid mobile robot with minimum mechanism and switching its style of locomotion. On the basis of design method of hybrid mobile robots that was established in the study on Roller-Walker, hybrid mobile robot had design and named as "TITAN X" Figure 2.1, which is a quadruped walking machine that combines the properties of leg and track.

The designed special driving system that combines the functions of tracked locomotion with those of drive transmission for driving the knee joint. This is belt driving system that has not only the functions of drive transmission to trim weight of the end of the leg, but also those of tracked locomotion for moving. TITAN X is about 900 millimeters long, 600 millimeters wide, 29 kilograms weight. By combine both, make a good waking ability and tracked locomotion and TITAN X walked on irregular terrain and made tracked locomotion on regular terrain. In addition, TITAN X was able to show high-performance motion such as hybrid motion that combines the properties of leg and track.



(a) (b)

Figure 2.1: Position Mode: (a) Walking position and (b) Wheel position[11]

2.3. Wheel-Leg Hybrid Mobile Robot to Realize a Large Wheel Diameter

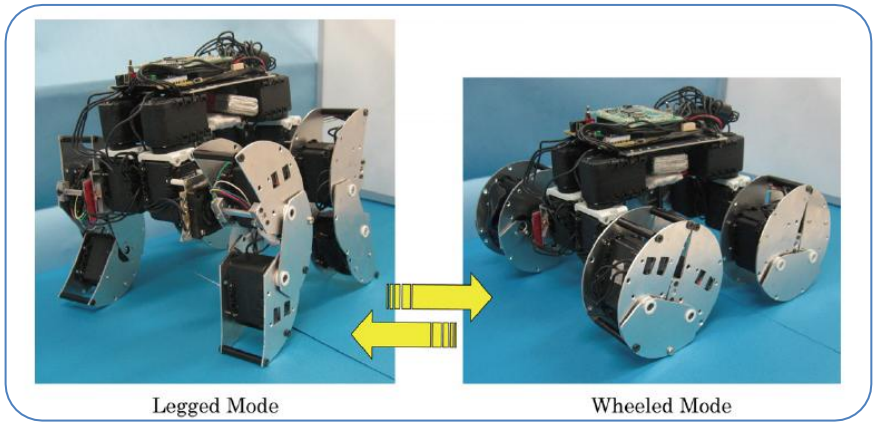


Figure 2.2: Wheel-Leg Hybrid Mobile Robot to Realize a Large Wheel Diameter

These journals focus on comparison with the previous wheel-leg module which divides by three type of wheel - small wheel, large wheel and retractable wheel. Small wheel face with difficulties of configuration to climb a small single-step or traverse a single-gap by wheel mode but when it is in walking mode, thanks to the small footprint, the mobile robot can select the position of the end of the foot on rough terrain. For large wheel it easy to configuration to climb a small single-step or traverse a single-gap when it is in wheeled mode[2]. On the other hand, when it is in walking mode, because of the large footprint, it is difficult for the mobile robot to select the position of the end of the foot on rough terrain. In addition, the motion range of the leg is limited. Both types of wheel can take the wheeled mode and legged mode at the same time but the motion control of the robot becomes quite complicated especially on rough terrain with a complicated surface structure. Therefore, retractable wheel is most suitable because it is easy for this type of mobile configuration to climb the small single-step or traverse the single-gap[2].

2.4 Roller-Walker

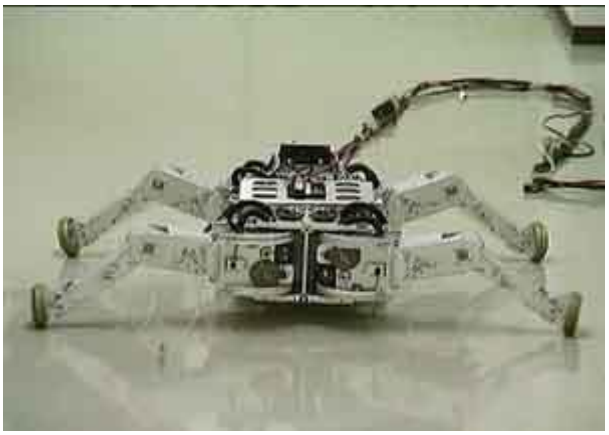


Figure 2.3: Roller-Walker[12]

In the past, active wheels were often used for wheeled robotic system. However installation of active wheels limited walking machine's ability very much. Because active wheels need big equipment or machines to operates such as actuators, brake mechanism and steering mechanism. This equipment is so heavy and massive which it's not practical solution for walking locomotion which has many degrees of freedom to generate. "Roller-Walker" is a mobile with a special foot locomotion mechanism which changes between feet soles for the leg mode and passive wheels for the wheel mode. Roller-Walker can practical use the installed actuators for walking, in additional weight become the advantages because is very light. The wheeled locomotion is based on the same principle of roller-skating. Figure 2.3 shows prototype robot model. The height is 0.25 m; the left/right width is 0.6 m; the front/back length is 0.5 m; and the total weight is 24 kg. Passive wheels were equipped on the tips of each TITAN VIII leg and also installed small actuators for the ankle change. The additional weight is only 7% of TITAN VIII[11]. The camber angle of passive wheel against the ground is always kept 90deg by parallel link mechanism using wire and pulley. Both right and left legs are moved symmetrically to cancel the lateral reaction force. It was demonstrated by experiments that wheeled locomotion can generate the velocity of 0.8 m/s over twice as large as the walking speed[12].

2.5 Autonomous Quadruped Robot

This robot was presented by UTM student for his final year project. This robot proposed hybrid leg-wheel mechanism and uses 14 servo motors as actuator.12 servo motors was used for the joint and additional two servo motors for wheel mode. This robot used one analog distance sensor for sensing the obstacles, reacts according to the situation and has the ability to climb over the obstacle. PIC 18F4550 microcontroller was used as the brain of robot. Acrylic and aluminum plate was used as the robot chassis and structure due to its light weight, soft but strong material and solid. The robot has the capabilities to perform optimization of gait patterns on a legged mode and the implementation of wheel mode on flat surface. This robot has variety modes of movement such as walking and turning with legged mode, implementation of wheel mode on flat surface, pass forward obstacles, climbing up the obstacles, obstacle avoidance and high speed walking mode. All those modes are activated autonomously by a looping program with mode selection. Figure 2.4 shown autonomous quadruped robot.

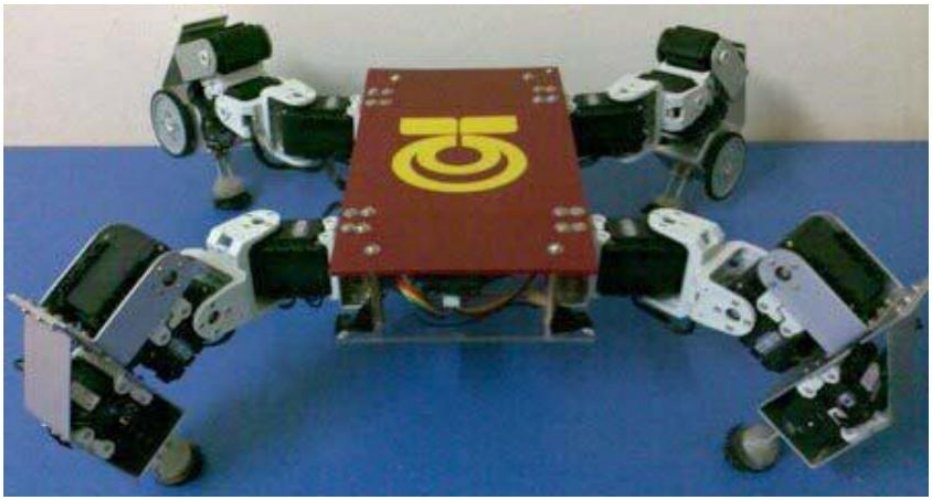


Figure 2.4: Autonomous Quadruped Robot[5]

2.6 Forward Movement And Turning

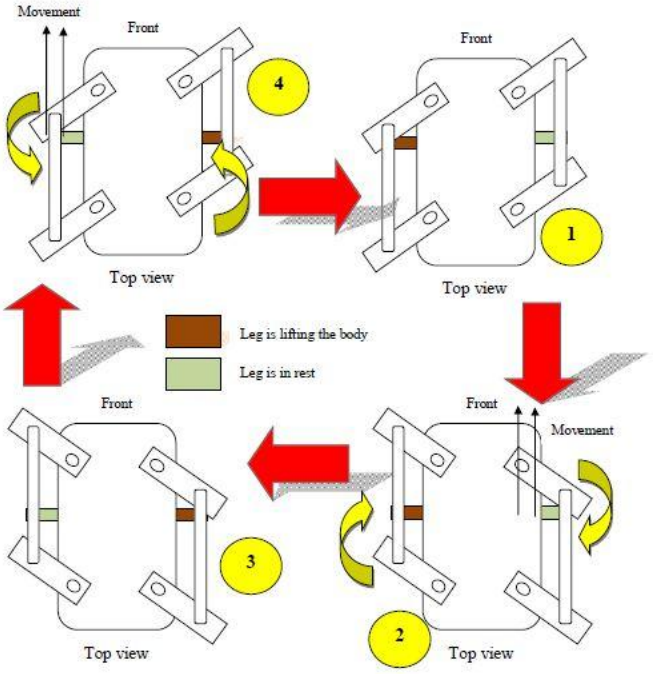


Figure 2.5: Forward Movement And Turning[4]

In this robot, planning is needed to make sure robot can move so by turning movement in a forward movement of the robot only. Firstly, in forward position is the right leg, left leg will lift up and move to backward position and centre leg is lifting the body at left side. Then right leg is moving to backward position which makes a robot body move to forward at right side. At the same time, left leg move to forward position but there is no effect to the body because the left body is still in lifting condition. The details of the robot mechanism are shown in figure 2.5 at no 1 and no 2. After that, at the centre leg the position will be change which make the robot body is lifting up at right position. Then left leg is lifting up and moving to backward position which makes a robot body move to forward position at left side. At the same time, right leg move to forward position but there is no effect to the body because the right body is still in lifting condition. Combinational of forward movement of left and right side makes the forward movement of the robot. The details of robot mechanism are represented in figure 2.5 at no 3 and no 4.

CHAPTER 3

3.0 METHODOLOGY

3.1 Introduction

This chapter will discuss the methodology of the project. The methodology that needed to be taken has been determined to make this project become more successfully. This chapter will describe the development methodology and guidelines to build a well quadruped motion robot. In order to meet the objective, three aspects must be taken into consideration. The first one is the hardware or mechanic structure of the small-scale. Then the related circuitry for the control system was constructing. Finally, the control algorithm was developing using the software application.

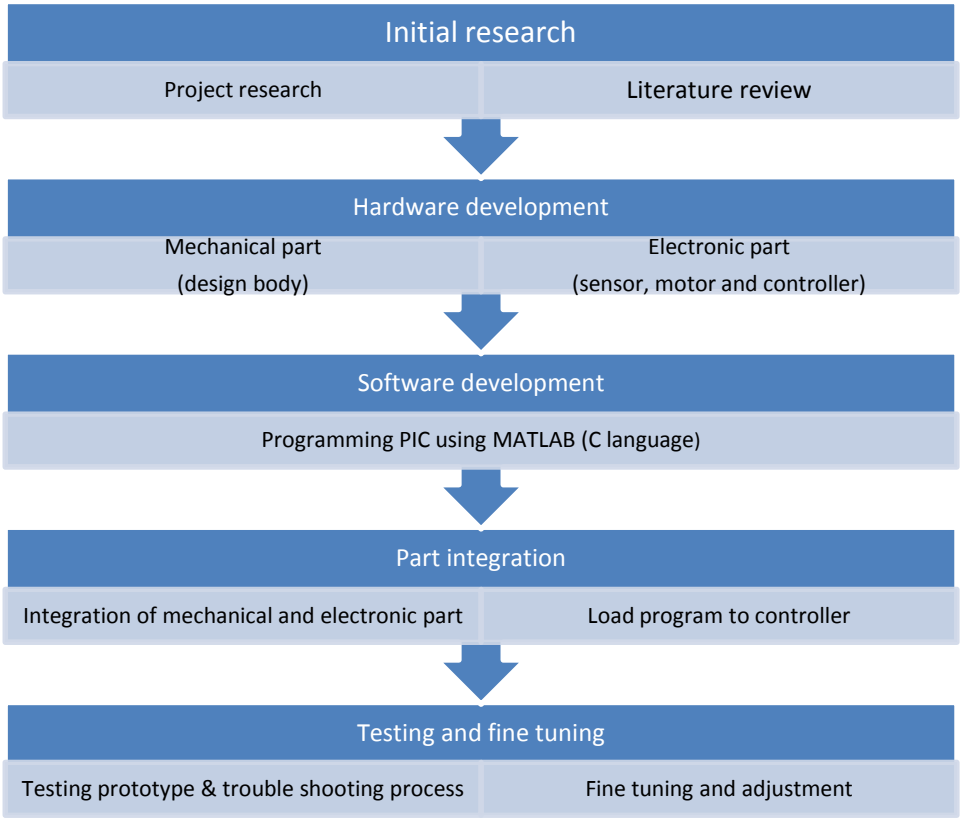


Figure 3.1: Flow of Methodology

3.2 Mechanical Part

The prototype of the quadruped motion robot chassis and the locomotion mechanism of its quadruped leg had been designed and developed. The full design of the prototype will develop by using aluminum plate and acrylic. For the leg design, the 2 servo will joint together to make a link and other servo will joint with bracket. The end of the servo will attach with DC motor and tire. This illustrated as shown in Figure 3.2.

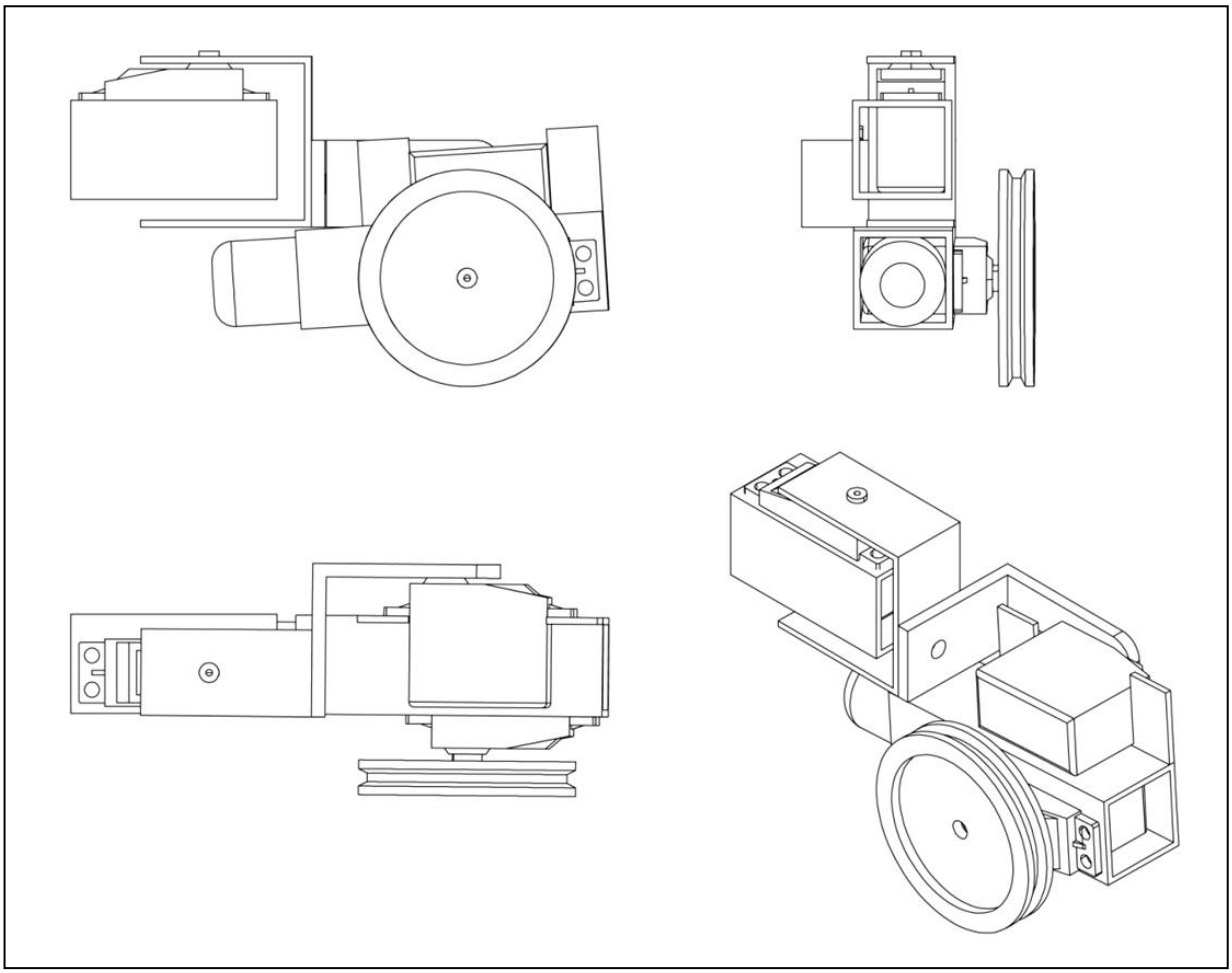


Figure 3.2: Leg Design

3.2.1 Mechanical Design

The illustration below summarized the quadruped robot structure and mechanism design.

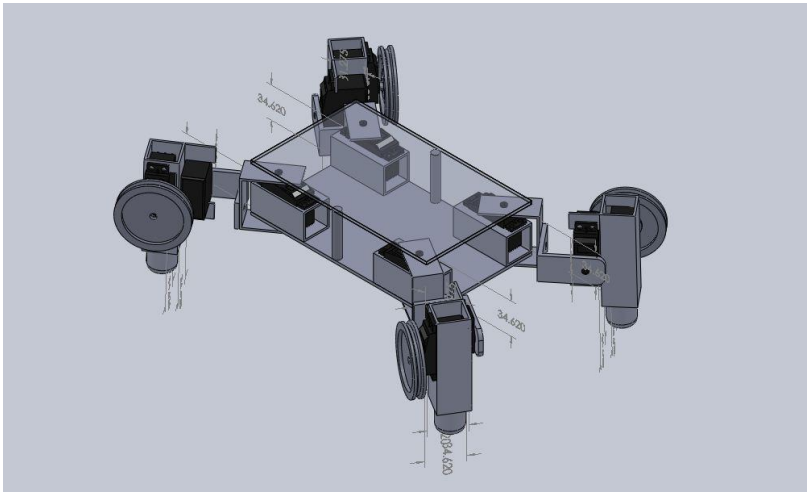


Figure 3.3: Leg Mode Design

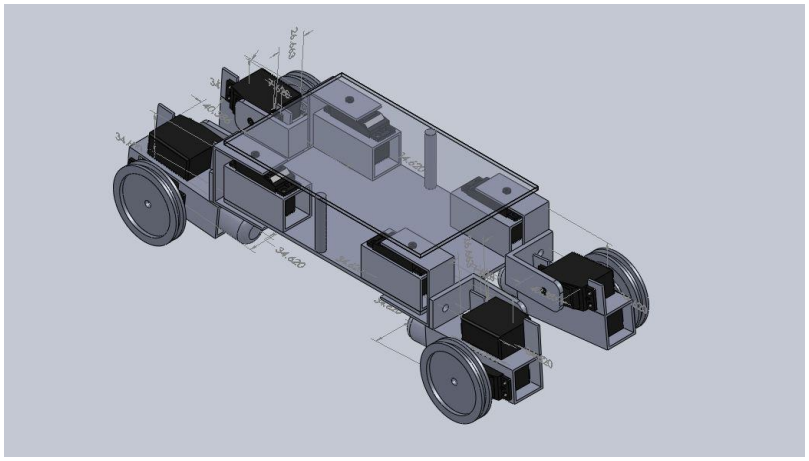


Figure 3.4: Wheel Mode Design

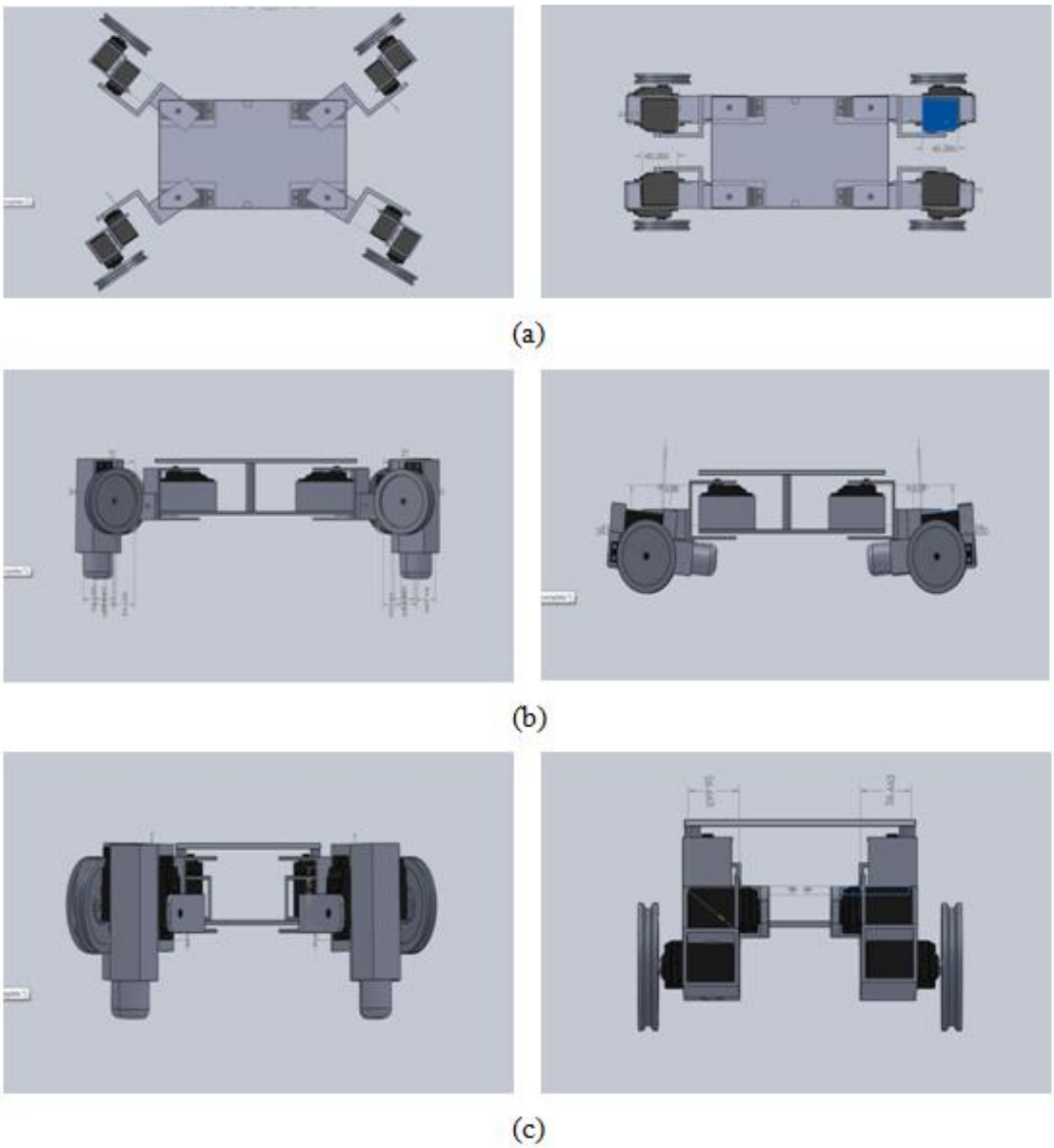


Figure 3.5: Overview: (a) Top view (b) Side view (c) Front view

3.3 Hardware Part

Hardware is the mechanical and electronic parts that are put together to build part of project. It will have to function well and perform according to the determined function as it will be considered failure if the hardware parts fail to function properly. Hardware design can be summarized in Figure 3.6. This figure portrays the connection of the mechanical components and how it's related to the control system. As shown in Figure 3.6, 4 servo controller were connected to the PIC18f4520. The microcontroller will control the speed of the motor by controlling the PWM. Then it is also shown those IR sensors and analog distance sensor were attached to the microcontroller. The microcontroller will control the speed of the motor with comparison between the nominate distance and actual distance then will response by calculating the desired speed. For servomotor will connect to servo controller, then servo controller will control by the microcontroller.

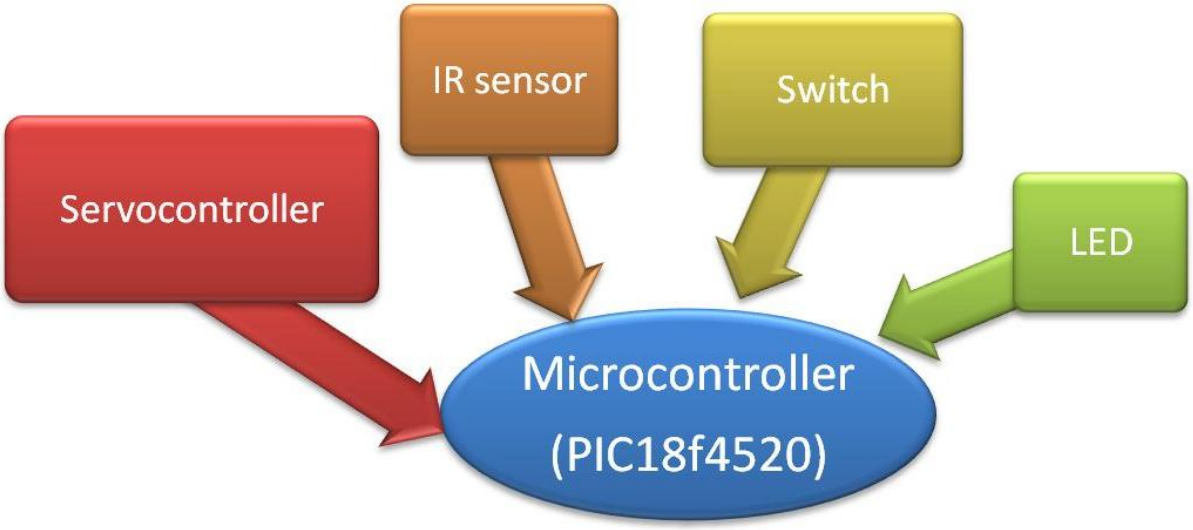


Figure 3.6: Map of Hardware Part

3.3.1 Microcontroller

A microcontroller is a small computer on a single integrated circuit containing a processor, memory ROM and RAM, and programmable input/output peripherals. Microcontrollers are used in automatically controlled devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, toys and other embedded systems which contact to the microcontroller. Therefore, PIC18F4250 microcontroller was used in this project because of its low power with wide operating voltage range; 2.0V to 5.5V, 4x Phase Lock Loop (PLL) – Available for Crystal and Internal Oscillators with Two External RC modes, up to 4 MHz and Two External Clock modes, up to 40 MHz, up to 10 MIPS performance, C compiler optimized RISC architecture and provide 10 bit, up to 13 channels Analog-to-Digital Converter (A/D) module. The device is manufacturing using Microchip's high-density non-volatile memory technology. With high speed FLASH/EEPROM technology on a monolithic chip, the Microchip PIC18F4250 is a powerful computer that provides a highly flexible and cost effective solution to many embedded control applications. Microcontroller will run 56 based on program that user implemented in this chip. In this project, Microchip PIC18F4250 microcontroller runs at 20 MHz with 8Kbytes of Flash memory and 256 Bytes EEPROM[8].

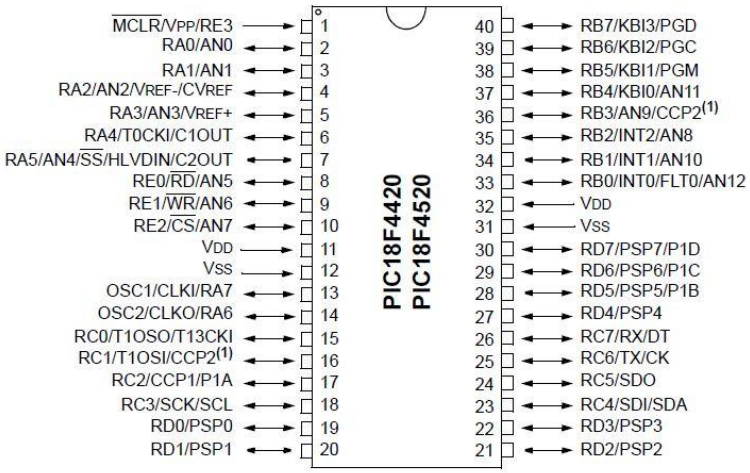


Figure 3.7: Microcontroller PIC18F4520[8]

3.3.2 Servomotor

Figure 3.8: Servomotor HD-4180BB

A servomechanism or servo is an automatic device which uses error-sensing feedback to correct the performance of a mechanism. The term correctly applies only to systems where the feedback or error-correction signals help control mechanical position or other parameters. Servo motors Figure 3.8 has been used to move the mechanical part control by electronics circuit.

In this project Digital servos will be used, which have lot significant operational advantages over standard servos, even coreless versions. Digital servo differs, is in the way it processes the incoming receiver information, and in turn controls the initial power to the servomotor, reducing the deadband, increasing the resolution and generating tremendous holding power. Therefore Servo motors are very important and useful in robotics.

3.3.3 IR Sensor

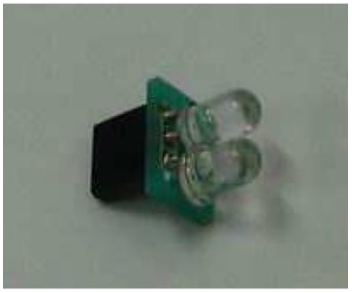


Figure 3.9: IR Sensor

Infra-red (IR) sensor used the concept of reflection of light to function. Transmitter transmits the IR packet to an object while receiver receives the packet sent after the light reflected from the object. Figure 3.9 show the position of both transmitter and receiver diode and the way of the IR sensor operate. From the figure detection or reflected packets ranges up to 10 mm from the object. However, the ranges of transmit and receive depend on type of diode used. In normal condition where no packets receive, the pin goes high (logic 1) but, after receiving IR packet, the pins grounded (logic 0). This concept represents the digital logic and easily adapted for this project. IR sensors used as obstacle detection sensors. It gives ability to the robot to avoid any potential collision.

3.3.4 Servocontroller

Figure 3.10: Servocontroller SC16A

RC Servo motor controller which a contoller of servomotor. 16 independent standard RC (Remote Control) is designed to control servo motors simultaneously in a single board. Each signal pin is able to generate servo pulses from 0.5 ms to 2.5 ms, which is greater than the range of most servos, further it also can operate 180 degrees. Through UART serial communication, SC16A can be combine in 2 boards to offer independent control over 32 RC servo motors simultaneously. The controller of SC16A can either be control by a PC desktop, Laptop with USB port, or microcontroller with UART communication interface. Both USB and UART interface present a flexible communication, fast and easy to use in feature. With USB, user is able to get it running within 5 minutes time. Figure 3 show the servo controller, SC16A with the connection of servo motors.

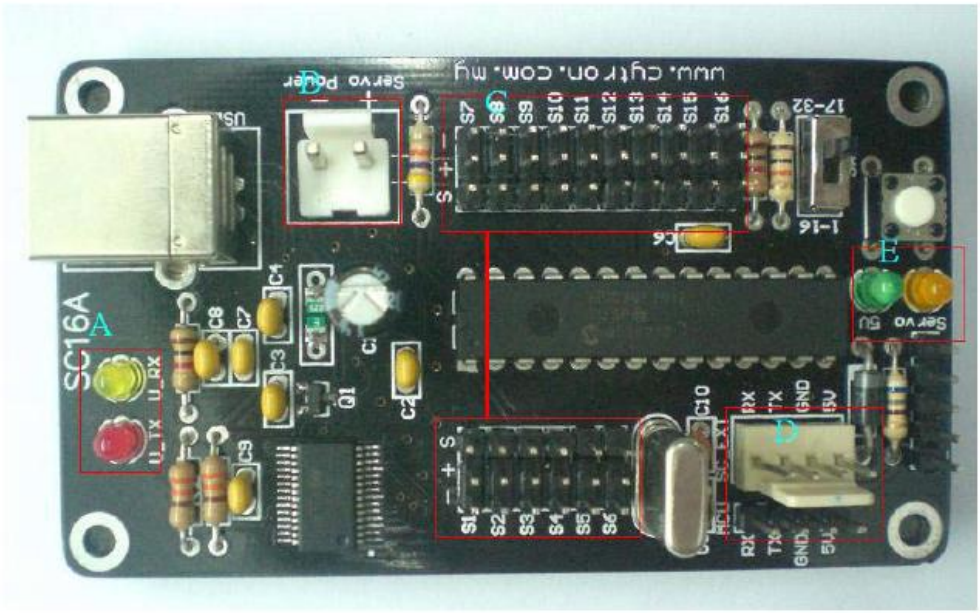


Figure 3.11: : Part of Servocontroller SC16A

Table 1: Label of Function Servocontroller

Label	Function
A	Led as indicator if there any signal transfered or received from PIC
B	5V,6A to supply the servormotor
C	16 channel pins for servomotors
D	Rx(Receiver), Tx(Transmiter), 5V and GND pins is use to connect to PIC
E	Indicates if powwer supply from servo and 5V are supplied

The servo controller, SC16A has been designed with capabilities and features of: [9]

- 16 channels: Servo driven independently
- Extendable to 32 Channels: Two controller linked together to drive 32 servos
- Optional Position Reporting: User may request position of an individual servo.

- Optional Servo Ramping: Choose one of 63 ramp rate (speed rate) for each servo.
- Sample GUI for computer*: User may control the servo via sample GUI software.
- Resolution: 1.367us.
- UART: 9600 baud rate
- Servo pulse: 0.5ms to 2.5ms.

3.4 Software And Programming Design

Programming languages can be used to create programs that control the behavior of a machine and/or to express algorithms precisely. Main is where the association of movement algorithm and sensor responses takes place. Depending on sensors response, the main program will decide which movement algorithm will be selected. The code algorithm must be developed to simply the programming process. The algorithm is represented by the flow chart in Figure 3.12.

Figure 3.12 show how the program works in the quadruped motion robot. Firstly, when the switch power suppply is on, the robot will be initialize before mode selection will make. Initialize means the robot will be at the original position. After that it will enter to the selection mode. This selection will be set by button. Button 1 will indicate the leg mode, button 2 will indicate the wheel mode and button 3 indicate the obstacle mode.

When Button 1 is been press, robot will starts walking forward and program will loop for 5 times for walking mode. If Button 2 is been press, robot will starts move forward by wheel. If Button 3 is been push, robot will starts move forward by wheel. During its moving by wheel, if sensor 1 or 2 sense any obstacle in front, robot will stop.

When sensor 1 and 2 senses the obstacle, it will rotate to the left by leg mode in 6 steps after delay in 5 seconds. Then, the robot will move to initial position after delay in 5 seconds. If there are no obstacles detected, the robot will maintain move to forward by wheel mode. Those are the flows of programming algorithm and they are continuously until the main switch is turned off.

Figure 3.12: Flow Chart

CHAPTER 4

4.0 EXPERIMENT AND RESULT

4.1 Communication of Servocontroller(SC16A) and PIC18F4520 Microcontroller

Servo controller, SC16A, is one way we can control the position of angle and speed of servo motors continuously and more accurately. Besides, in this thesis the servocontroller can control 16 units of servo motors for each servo controller at the same time. Servo position has their ranges which are between 0-1463. Value of 0 indicates that the position of shaft at position 0 degree and value for 1463 servomotor will move the shaft to 180 degree. The resolution of SC16A that can be measured is 1.367us. Basically, pulse that generated will start from 0.5ms, so after generating it will increase the duty cycle by increasing the timing of active pulse according to value of position. Thus, following formula show the duty cycle of pulses generated:-

Duty cycle = (Resolution x Servomotor Position/Angle) + 0.5ms .....(1)

= (1.367us x Servomotor Position/Angle) + 0.5ms .....(2)

Duty cycle increase, the faster servo will rotate to its position but the value of '0' will disable the speed, thus provide normal speed. Servomotor will rotate according to its own maximum speed. 63 ramp rates allow the user to set the speed of each servo. Decimal value of '1' will indicate that the servo run at slowest speed and

decimal value of ‘63’ will run at the fastest speed. At each 20ms interval, the current servo position will increase or decrease with the speed value depending on whether the position is greater or lesser than the new position.

Speed of servomotor is depending on the brand of servo motors because they have different type of resolution which related to duty cycle. Therefore, different type of servo would result in different speed because of percent of duty cycle. For servo HD-4180BB, the approximate time of speed range from 0 degree to 180 degree of rotation is shown in Table 2.

Table 2: Speed Range from 0 degree to 180 degree of Rotation

Decimal Value	Speed (seconds)
0	0.30
1	90.00
10	13.00
20	6.00
30	5.14
40	4.60
50	3.70
60	2.20
63	1.90

4.2 Program debugging

After the quadruped motion robot such as hardware, structure, electronic system and basic robot locomotion program are tested, programming will be the next stage to enhancement of the robot where more dynamic movement and interesting on gait pattern. On this stage, creativity and observation of hybrid legged-wheel robot

and characteristic play an important role to enhance the quadruped robot movement and body more flexibility. USB ICSP PIC Programmer offers low cost yet reliable and user friendly PIC USB programmer solutions to program popular Flash PIC MCU which includes PIC12F, PIC16F and PIC18F family. For the development of programmer and debugger, PICkit 2 Development Programmer/Debugger offers a low-cost development programmer and it is capable of programming on most of the Microchip's Flash microcontrollers and serial EEPROM devices. In MPLAB IDE, PICkit 2 supported device is selected and then from either the Debugger or Programmer menu to add debugging or programming functions to MPLAB IDE, respectively. The MPLAB IDE software which is able to support the debugging and programming process is fully utilized.

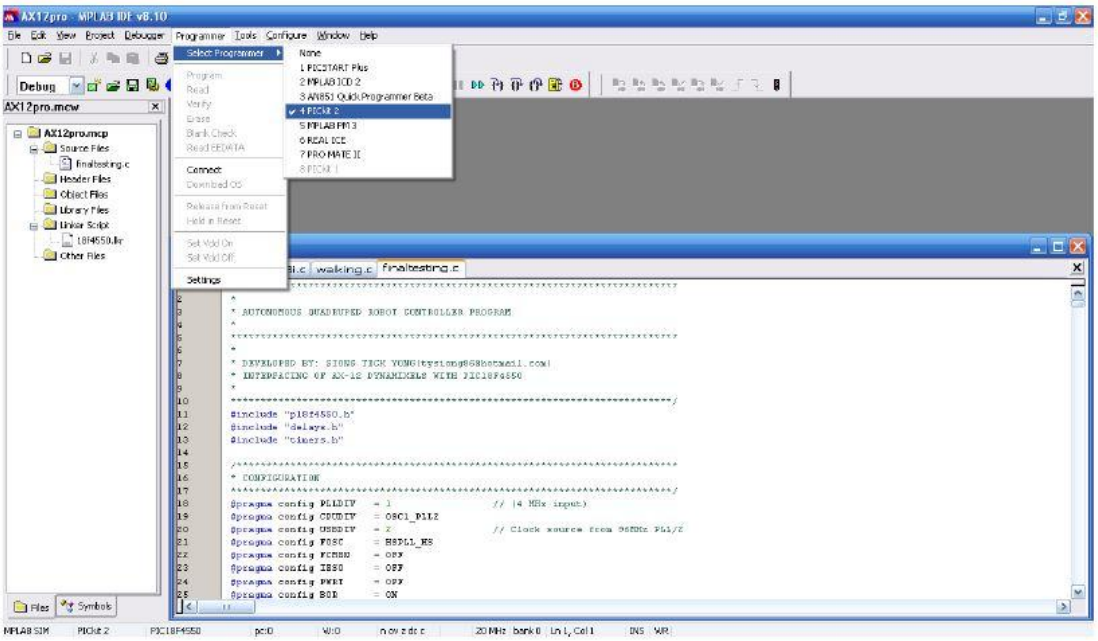


Figure 4.1 The MPLAB IDE programming platform.

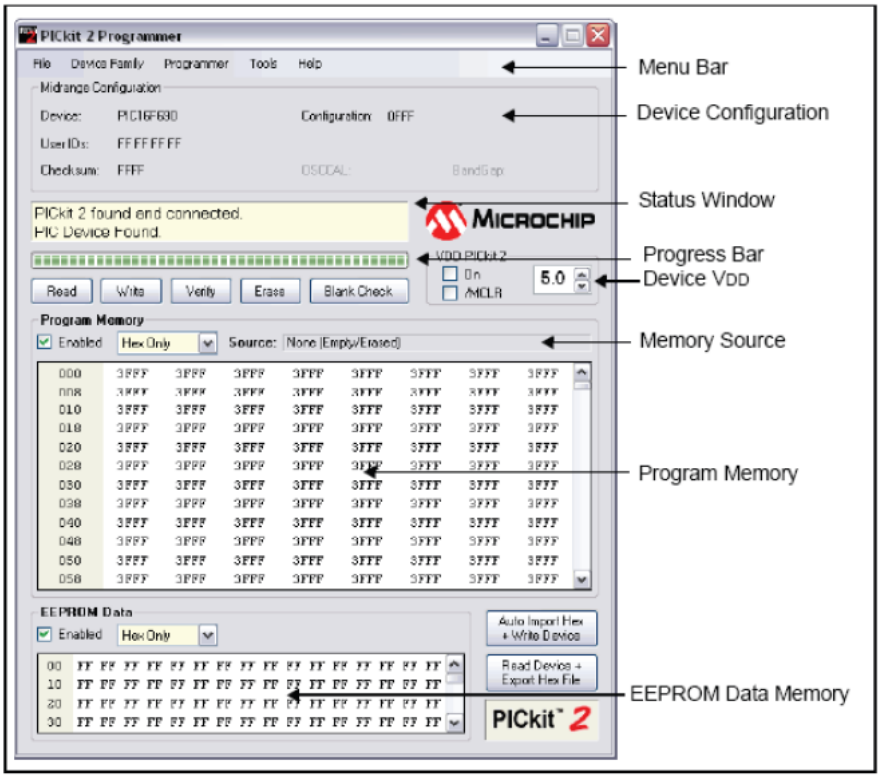


Figure 4.2 PICkit 2 Programmer Applications

4.3 Mode Selection

Quadruped motion robot consists of 3 mode selection. A push button is attached and connected to microcontroller as manual modes selection (portD1, D2, and D3).

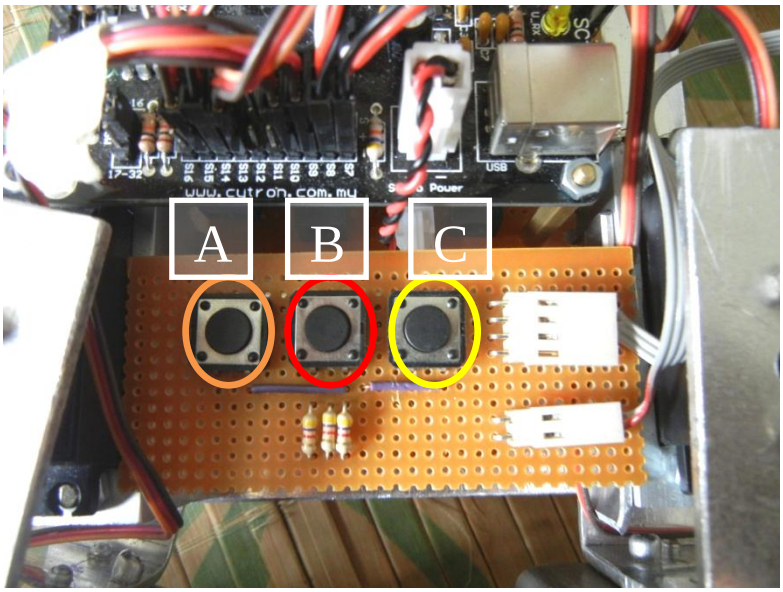


Figure 4.3 Manual mode selection on robot.

4.3.1 Mode Selection Function

Table 3: Quadruped robot's mode selection and its function for each mode selected.

Mode selection	Function
A	Legged mode including walking gait locomotion, going forward and backward
B	Wheel mode including wheel gait locomotion, going forward and backward
C	Wheel mode including wheel gait locomotion, obstacles avoidance, turning left and Legged mode including walking gait locomotion,

4.4 Quadruped Robot Formation

The following figure shows the formation of different pattern and gait locomotion.

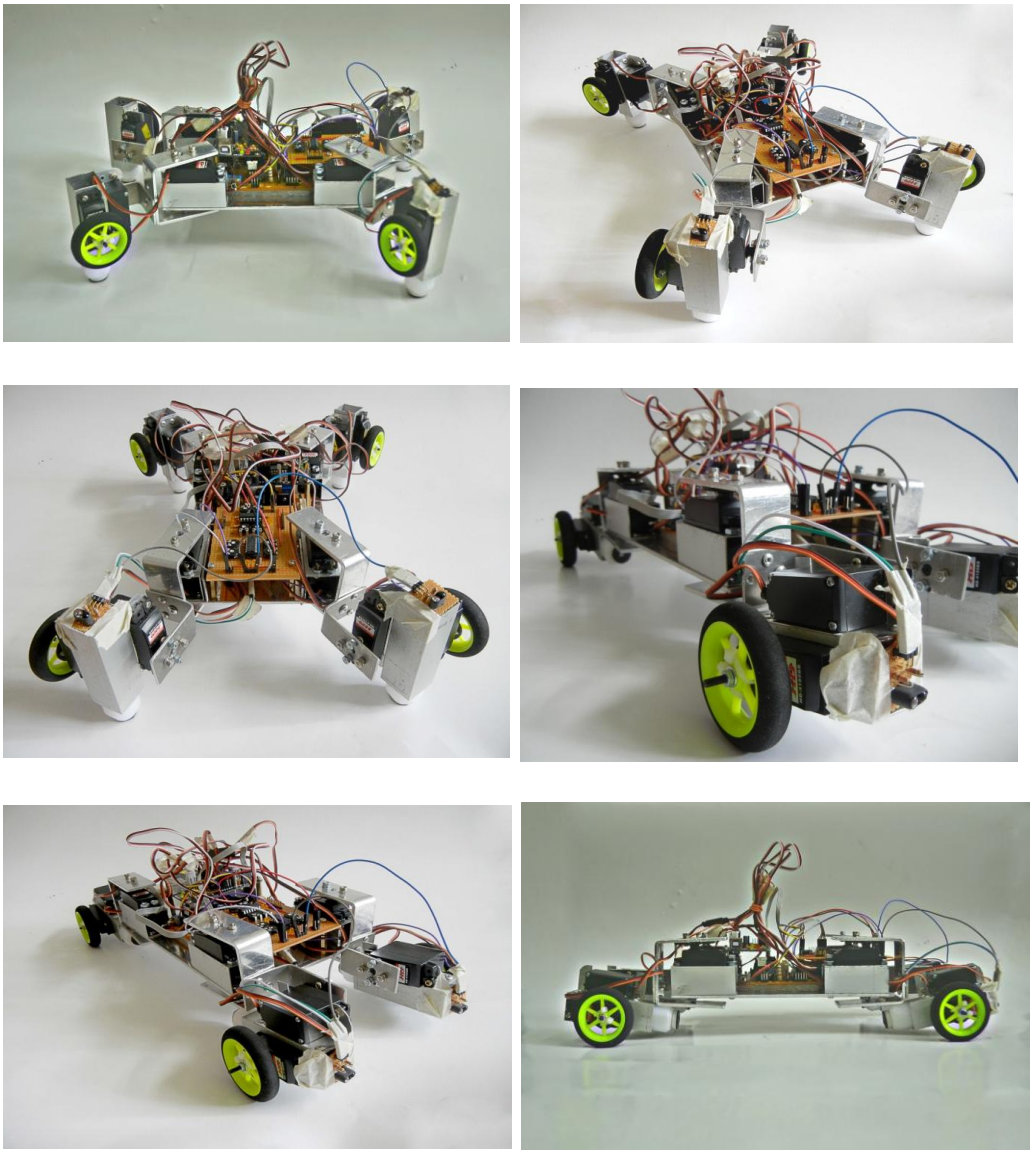
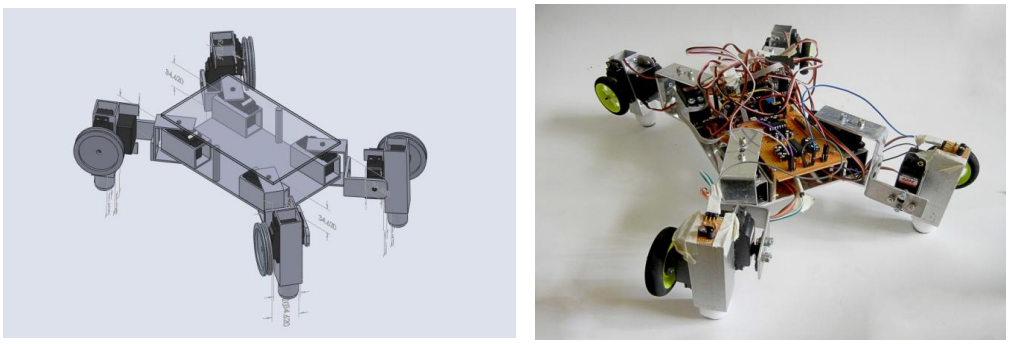
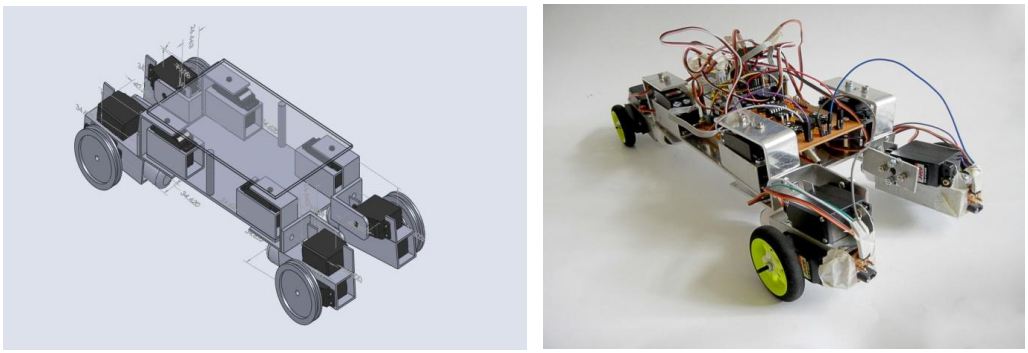


Figure 4.4: Quadruped Robot Formation

4.4.1 Comparison between the design and hardware



(a)

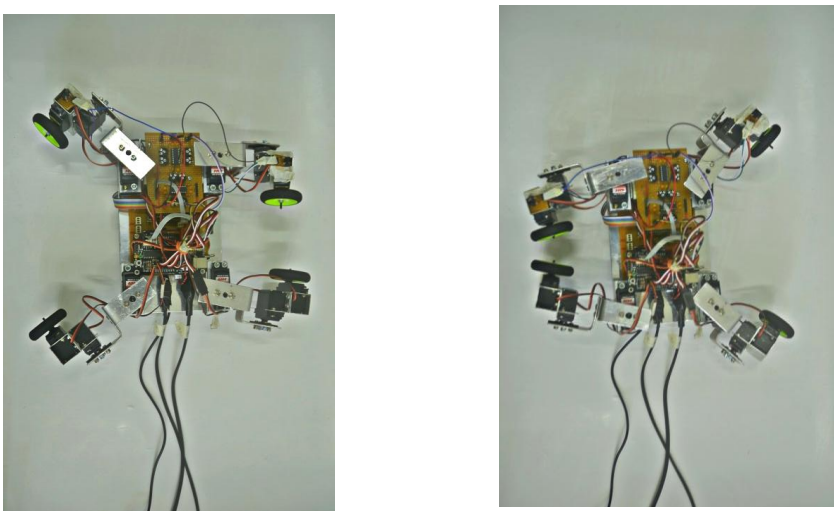


(b)

Figure 4.5 Comparison: (a) Leg mode and (b) Wheel mode

4.4.2 Walk forward by leg

Movement is one of the objectives in this thesis, so to make sure it move plan is need to make sure robot can move in a forward movement of the robot only. Firstly, robot will initialize on its position of leg mode, both front and back leg are close together like in wheel mode. Then, left front leg of the robot will lift up and move forward in about 45 degree. While at same time, left front leg will move to centre and right back leg move back about 45 degree, this is the way how the robot to push the body forward. Next, the robot will go back achieve as initial position by lift up the right back leg and move forward but in the ride side. The robot will repeat the same movement, lift front leg and move forward. While right front and left back leg move to push body forward. One sequence of forward movement achieve as the robot get in intial position back.



(a) **(b)**

Figure 4.6: Walk forward by leg :
(a) Left front leg lift up and move forward and (b) Right front leg lift up and move forward

4.4.3 Obstacle Avoidance

Avoid obstacle is most difficult behavior in this part because robot will using IR sensor as device to detect the object. Firstly, the robot will be in wheel mode, after the robot detect the object or obstacle in front of the robot it will change to the leg mode to avoid the obstacle. Then, the robot will turn left by lift up left front leg and right back leg of the robot about 90 degree. Next, the robot will start to turn by pushing all 4 leg in 90 degree. After that, the robot will repeat the same step until it turns left in right position. This is the way how the robot avoid the obstacle by turn the body to the left.

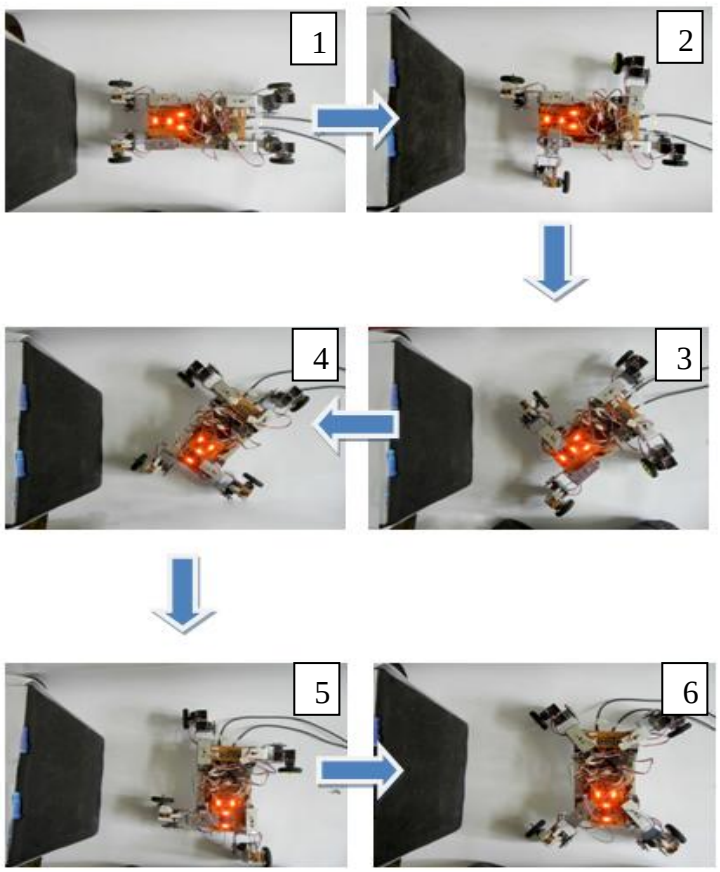


Figure 4.7: Obstacle Avoidance

4.4.4 Electronic part

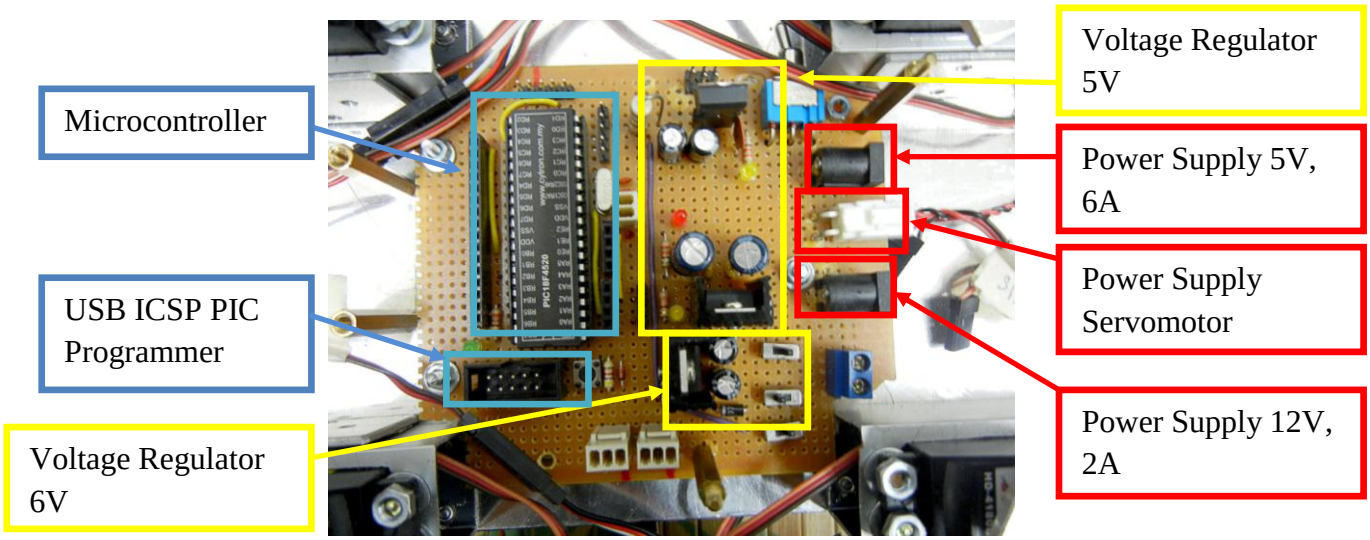


Figure 4.8: Main Board

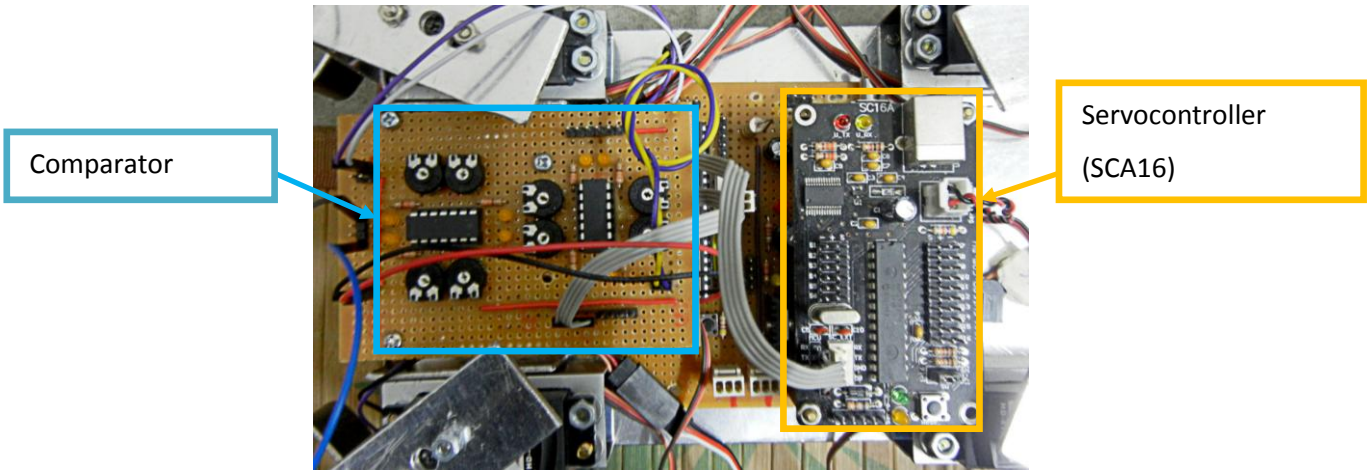


Figure 4.9: IR sensor board and Servocontroller (SCA16)

CHAPTER 5

5.0 DISCUSSION AND CONCLUSION

5.1 Discussion

Based on the achievement and respond from the lecturer and student, the Quadruped Motion Robot project is seen successfully achieve its project scope and objectives as discussed in chapter one. In the beginning, the robot body was made from the acrylic. This material is easy to be shape, but due to its softness, the material cannot handle the total weight of the robot. The use of acrylic has cause the robot to be unstable especially when the mode changing. Therefore a solution has been made by using aluminum plate for the body part. The use of aluminum is proven to be success when it provides more stability for the robot compare to the previous material. Even though this modification has caused the weight of the robot to be drastically increased, it does not cause any problem for the robot at all. Therefore the use of aluminum for body part is perfect for the robot.

For obstacle detection, IR sensors were used on the robot. The IR sensor install on the robot has been proven to work successfully where it is able to complete its objective by detecting the obstacle for robot even though the reaction to detect the obstacle vary long. The microcontroller use for the robot is PIC18F4520 since this PIC is able to support C programming. The use of PIC18F4520 and C programming

has speed up the interface for the robot. The problem encountered in electronic part of the robot is the low current supply for the servo motor. In the beginning, voltage regulator 6V was use to supply the current to the circuit and the servo motor. The voltage regulator is able to supply only 1A current which enough to the circuit, however the current supply needed for the servo motor is 6A therefore it is insufficient. Therefore a current booster was made to provide 6A current.

However, the current booster that was made cannot even generate current as high as 3A. This could be due to the use of unsuitable resistor. In addition to that, the transistor use for the current booster will overheat whenever the current booster operates. Therefore another solution was made by switching the battery to a power supply with supported 5V,6A and 12V,2A which recommended by Cytron.

For the robot communication, the interface between the PIC and the servo controller is a success. The servo controller is able to operate according to the input given in the PIC. However the interrupt function was not implemented in the microcontroller. This has caused an inconvenient in the robot application where whenever the mode selection button is pushed, it will cause a very long delay in the system before it obtains the input.

5.2 Suggestion And Future Development

This project has manage to achieve its objective by able to change mode between the leg mode and the wheel mode. However there are still improvements that can be done for future development. For future project, more sensors could be installed to indicate the surrounding environment. After several testing and demonstration, it is found that the IR sensor that were use does not cover long range obstacle, therefore more sensor with wider coverage is needed. An example of this could be ultrasonic sensor.

Another recommendation that can be done is by installing sensor in both leg and wheel mode. At the moment, the sensor only installed for the wheel mode, which

means the obstacle avoidance can only be done during wheel mode. So another set of sensor should also be installed to leg mode so that the obstacle avoidance system can be used in either wheel or leg mode. In addition to that, LCD also could be installed to the robot to indicate which mode it is at the current time.

The final recommendation that can be suggested for future development is by using more degree of freedom to the robot. By using higher degree of freedom, the robot movement will be easier and smooth. More movement and orientation can be applied in the robot to increase its mobility and agility.

5.3 Conclusion

The Quadruped Motion robot platform brings a great significant to the robotic and artificial intelligent field. The hybrid leg-wheel concept can be widely applied neither student nor college who do research into it. A variety of dynamic behaviors were successfully implemented into a hybrid leg-wheel platform. The placement of wheels at the foot of the legs proved to significantly widen the scope of flexible the dynamic behavior for a quadruped platform.

Most excited is the ability of robot to avoid obstacles. Based on the achievement and respond from the lecturer and student, the Quadruped Motion Robot project is seen successfully achieve its project scope and objectives as discussed in chapter one. With the strength of 8 servos motor that brings to a flexible degree of freedom to the robot and 4 servomotors use as wheel it makes the locomotion and movement of the robot more alive. The inspiration for this robot—the biological world is filled with examples of legged locomotion. Despite their limitations legged robots and legged mobile platforms offer a number of advantages over their wheeled or tracked counterparts; indeed this motivates their continued study and development. A number of legged systems, humanoid and others have

been developed commercially as well as within academia and industrial research centers.

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APPENDIX A

Gant chart

Semester 1, Session 2011/12

Weeks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Project Proposal															
Background Study															
Search releated information															
Choosing and buy component															
Design mechanism															
Build leg mechanism															
Build body															
Robot Building															
Design /build circuit															
Report/thesis writing															
Presentation															

Semester 2, Session 2011/12

Weeks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Search releated information															
Robot Building															
Design /build circuit															
Parts Assembly															
Programming															
Testing															
Modification															
Demo Preparation															
Report Writing															
Presentation															
Thesis Compilation															

APPENDIX B

Source Code

```
//=============================================================
//        Include
//=============================================================

#include <p18f4520.h>                    // this sample code is using
                                         18F4520 !!
#include "delays.h"
#include "usart.h"

//=============================================================
//        Configuration
//=============================================================

#pragma     config OSC = HS              // HS oscillator
#pragma     config FCMEN = OFF           // Fail-Safe Clock
                                         Monitor disabled
#pragma     config IESO = OFF            // Oscillator Switchover
                                         mode disabled
#pragma     config PWRT = OFF            // PWRT disabled
#pragma     config BOREN = OFF           // Brown-out Reset
```

```
                                                    disabled in hardware and
                                                    software
#pragma     config WDT = OFF                        // WDT disabled (control
                                                    is placed on the
                                                    SWDTEN bit)
#pragma     config MCLRE = ON                   // MCLR pin enabled; RE3 input
                                                    pin disabled
#pragma     config PBADEN = OFF                     // PORTB<4:0> pins are
                                                    configured as digital I/O
                                                    on Reset
#pragma     config CCP2MX = PORTC                   // CCP2 input/output is
                                                    multiplexed with RC1
#pragma     config LVP = OFF                        // Single-Supply ICSP
                                                    disabled
#pragma     config XINST = OFF                      // Extended Instruction
                                                    Set

//=========================================================
//      Define
//=========================================================

#define But1        PORTDbits.RD1
#define But2        PORTDbits.RD2
#define But3        PORTDbits.RD3
#define sens1       PORTbits.RD7
#define sens2       PORTDbits.RD6


#define L_Front         0x03
#define L_Back          0x01
#define R_Front         0x04
#define R_Back          0x02
#define L_Front1        0x0D
#define L_Back1         0x0F
```

```
#define R_Front1        0x09
#define R_Back1         0x07
#define L_TFront        0x0B
#define L_TBack         0x0E
#define R_TFront        0x0A
#define R_TBack         0x08


//=========================================================
//      Global variable
//=========================================================

static volatile unsigned int received_servo_position[0x11];     // Array declared
                                                                to store the
                                                                feedback position
                                                                of servo

//=========================================================
//      Function prototype
//=========================================================

void neutral();
void button(unsigned int mode);
void leg();
void wheel();
void obstacle();

void send_cmd(unsigned int num, unsigned int data, unsigned int ramp);
//UART transmit 4 bytes: servo number, higher byte position, lower byte position
  and speed
void delay(unsigned long data);                 //delay function, the delay time
void uart_send(unsigned char data);

//=========================================================
```

```
//        Main function                                (main fucntion of the program)
//============================================================
void main(void)
{
        unsigned int j, k, temp;
        unsigned char i;
        TRISC = 0b11000000;                             //set input or output
        TRISD = 0b00001110;

        //---------------------------------------------------------------------
        // Configure UART
        //---------------------------------------------------------------------
        OpenUSART( USART_TX_INT_OFF &           // Transmit interrupt off
                USART_RX_INT_OFF &              // Receive interrupt off
                USART_ASYNCH_MODE &             // Asynchronous mode
                USART_EIGHT_BIT &               // 8-bit data
                USART_CONT_RX &                 // Continuous reception
                USART_BRGH_HIGH,                // High baud rate
                129);


        while(1)
   {

      neutral();

      button (mode);

      switch(mode)
      {
         case 1 :
            leg();
            break;
```

```
            mode 2 :
                wheel();
                break;

            mode 3 :
                obstacle();
                break;
        }

    }
}

        CloseUSART();

}//main loop

//=========================================================
//          UART subroutine
//=========================================================

void send_cmd(unsigned int num, unsigned int data, unsigned int ramp)
{
        unsigned char higher_byte=0, lower_byte=0;

        if(0x01<=num<=0x16)
        {
                num=num|0x40;
        }

        higher_byte=(data>>6)&0x003f;
        lower_byte=data&0x003f;

                        uart_send(num);
                        uart_send(higher_byte);
```

```
                uart_send(lower_byte);
                uart_send(ramp);
}

void delay(unsigned long data)                  //delay function, the delay time
{                                                                       //depend
on the given value
        for( ;data>0;data-=1);
}

//=============================================================
//      Subroutine
//=============================================================

void uart_send(unsigned char data)
{
        while(PIR1bits.TXIF==0);                //only send the new data after
        TXREG=data;                             //the previous data finish sent
}

void neutral();
{
                delay(80000);

                        send_cmd(L_Front1, 603, 0);
                        delay(5000);
                        send_cmd(R_Back1, 550, 0);
                        delay(5000);
                        send_cmd(R_Front1, 860, 0);
                        delay(5000);
                        send_cmd(L_Back1, 950, 0);
                        delay(5000);

                        delay(80000);
```

```
                                //lurus
                                send_cmd(L_Front, 461, 0);
                                delay(5000);
                                send_cmd(R_Back, 250, 0);
                                delay(5000);
                                send_cmd(R_Front, 949, 0);
                                delay(5000);
                                send_cmd(L_Back, 1200, 0);
                                delay(5000);

}

void button(unsigned int mode);
{
        unsigned int x;

   while(1)
   {
   if (But1==0)
   {return x=1;}
   else if (But2==0)
   {return x=1;}
   else if (But3==0)
   {return x=1;}
        }
}

void leg();
{
            unsigned int i;

            delay(80000);
                                //45
```

```
send_cmd(L_Front, 1000, 0);
delay(5000);
send_cmd(R_Back, 567, 0);
delay(5000);
send_cmd(R_Front, 400, 0);
delay(5000);
send_cmd(L_Back, 913, 0);
delay(5000);

delay(80000);

for(i=0;i<5;i++)
{
delay(1000);
//45
send_cmd(L_Front1, 328, 0);
delay(80000);
send_cmd(L_Front, 754, 0);
delay(60000);
send_cmd(L_Front1, 603, 0);
delay(5000);
send_cmd(R_Back, 940, 0);
delay(5000);
send_cmd(R_Front, 360, 0);
delay(5000);
send_cmd(L_Back, 913, 0);
delay(5000);

delay(90000);

send_cmd(R_Front1, 1188, 0);
delay(80000);
send_cmd(R_Front, 680, 0);
delay(60000);
```

```
                                send_cmd(R_Front1, 860, 0);
                                delay(5000);
                                send_cmd(L_Front, 1150, 0);
                                delay(5000);
                                send_cmd(R_Back, 567, 0);
                                delay(5000);
                                send_cmd(L_Back, 500, 0);
                                delay(5000);

                                delay(80000);
                                }
}

void wheel();
{
        unsigned int j;

        send_cmd(L_Front, 461, 0);
                                delay(5000);
                                send_cmd(R_Back, 250, 0);
                                delay(5000);
                                send_cmd(R_Front, 949, 0);
                                delay(5000);
                                send_cmd(L_Back, 1200, 0);
                                delay(5000);

                                delay(80000);

                                send_cmd(L_Front1, 603, 0);
                                delay(5000);
                                send_cmd(R_Back1, 550, 0);
                                delay(5000);
                                send_cmd(R_Front1, 860, 0);
                                delay(5000);
```

```
                send_cmd(L_Back1, 950, 0);
                delay(5000);

                delay(80000);

                send_cmd(L_Front1, 1126, 0);
                delay(5000);
                send_cmd(R_Back1, 1144, 0);
                delay(5000);
                send_cmd(R_Front1, 293, 0);
                delay(5000);
                send_cmd(L_Back1, 355, 0);
                delay(5000);

                for(j=0;j<5;j++)
        {
                delay(80000);

                send_cmd(L_TFront, 1000, 0);
                delay(5000);
                send_cmd(R_TBack, 300, 0);
                delay(5000);
                send_cmd(R_TFront, 300, 0);
                delay(5000);
                send_cmd(L_TBack, 1000, 0);
                delay(5000);

                delay(800000);

                }
}

void obstacle();
{
```

```
unsigned int k;

send_cmd(L_Front, 461, 0);
                    delay(5000);
                    send_cmd(R_Back, 250, 0);
                    delay(5000);
                    send_cmd(R_Front, 949, 0);
                    delay(5000);
                    send_cmd(L_Back, 1200, 0);
                    delay(5000);

                    delay(80000);

                    send_cmd(L_Front1, 603, 0);
                    delay(5000);
                    send_cmd(R_Back1, 550, 0);
                    delay(5000);
                    send_cmd(R_Front1, 860, 0);
                    delay(5000);
                    send_cmd(L_Back1, 950, 0);
                    delay(5000);

                    delay(80000);

                    send_cmd(L_Front1, 1126, 0);
                    delay(5000);
                    send_cmd(R_Back1, 1144, 0);
                    delay(5000);
                    send_cmd(R_Front1, 293, 0);
                    delay(5000);
                    send_cmd(L_Back1, 355, 0);
                    delay(5000);

                    do{
```

```
delay(80000);

send_cmd(L_TFront, 1000, 0);
delay(5000);
send_cmd(R_TBack, 300, 0);
delay(5000);
send_cmd(R_TFront, 300, 0);
delay(5000);
send_cmd(L_TBack, 1000, 0);
delay(5000);

delay(800000);

}while(sen1==1 && sen2==1);


delay(80000);

send_cmd(L_TFront, 0, 0);
delay(5000);
send_cmd(R_TBack, 0, 0);
delay(5000);
send_cmd(R_TFront, 0, 0);
delay(5000);
send_cmd(L_TBack, 0, 0);
delay(5000);

for(j=0;j<10;j++)
{
delay(80000);

send_cmd(L_Front1, 603, 0);
delay(5000);
send_cmd(R_Back1, 550, 0);
```

```
delay(5000);
send_cmd(R_Front1, 860, 0);
delay(5000);
send_cmd(L_Back1, 950, 0);
delay(5000);

delay(80000);

send_cmd(L_Front, 754, 0);
delay(5000);
send_cmd(R_Back, 567, 0);
delay(5000);
send_cmd(R_Front, 656, 0);
delay(5000);
send_cmd(L_Back, 913, 0);
delay(5000);

delay(80000);

send_cmd(R_Front1, 1188, 0);
delay(80000);
send_cmd(R_Front, 400, 0);
delay(8000);
send_cmd(L_Front1, 603, 0);
delay(5000);
send_cmd(L_Back1, 1206, 0);
delay(80000);
send_cmd(L_Back, 700, 0);
delay(8000);
send_cmd(L_Back1, 950, 0);
delay(5000);
send_cmd(L_Back1, 950, 0);
delay(5000);
send_cmd(L_Front, 461, 0);
```

```
delay(5000);
send_cmd(R_Back, 250, 0);
delay(5000);

delay(80000);
}
for(k=0;k<10;k++)
{
delay(1000);
//45
send_cmd(L_Front1, 328, 0);
delay(80000);
send_cmd(L_Front, 754, 0);
delay(60000);
send_cmd(L_Front1, 603, 0);
delay(5000);
send_cmd(R_Back, 940, 0);
delay(5000);
send_cmd(R_Front, 360, 0);
delay(5000);
send_cmd(L_Back, 913, 0);
delay(5000);

delay(90000);

send_cmd(R_Front1, 1188, 0);
delay(80000);
send_cmd(R_Front, 680, 0);
delay(60000);
send_cmd(R_Front1, 860, 0);
delay(5000);
send_cmd(L_Front, 1150, 0);
delay(5000);
send_cmd(R_Back, 567, 0);
```

```
                delay(5000);
                send_cmd(L_Back, 500, 0);
                delay(5000);

                delay(80000);
                }

                send_cmd(L_Front, 461, 0);
                delay(5000);
                send_cmd(R_Back, 250, 0);
                delay(5000);
                send_cmd(R_Front, 949, 0);
                delay(5000);
                send_cmd(L_Back, 1200, 0);
                delay(5000);

                delay(800000);

                send_cmd(L_Front1, 1126, 0);
                delay(5000);
                send_cmd(R_Back1, 1144, 0);
                delay(5000);
                send_cmd(R_Front1, 293, 0);
                delay(5000);
                send_cmd(L_Back1, 355, 0);
                delay(5000);

                delay(800000);
}
```